EFFECTS OF APPLIED POTASSIUM, MAGNESIUM AND CALCIUM ON THE GROWTH AND CHEMICAL COMPOSITION OF LADINO CLOVER, SOYBEANS AND WHEAT

by

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INTRODUCTION

This investigation was undertaken for several reasons. First, an attempt was made to determine whether additions of Ca, K and Mg, alone or in various combinations, stimulated the growth of soybeans, wheat or ladino clover. Secondly, the influence of additions of Ca, K and Mg upon the uptake and accumulation of these elements and phosphorus by the plants mentioned above was investigated.

REVIEW OF LITERATURE

Considerable disagreement can be found among soil scientists relative to the effect of Ca/Mg ratio on plant growth. Miller (9) calls attention to the great difference of opinion among investigating scientists. The Loew-Lipman controversy on the subject of Ca/Mg ratios serves to illustrate this conflict. Loew tried to prove that each plant has its own Ca/Mg ratio at which it grows best. Lipman conducted a series of experiments with wide differences in Ca/Mg ratio and found no significant difference in plant yield.

Despite the fact that considerable experimentation has been done in the past with Ca/Mg ratios on various crops, further experiments with Kansas soils were undertaken because of encouraging results obtained recently by Sanik (11) on soil obtained from the Kingman location. Sanik concluded: "A varying Ca/Mg ratio in Kingman soil produced a different weight and height of plants grown." Also Sanik reported that the uptake of all the nutrient elements included in his study was affected by varying Ca/Mg ratios.

According to Miller (9), calcium percentage in plants varies from .4 to 8%. Calcium performs a physiological role in plant growth in the following ways: first, as an antidoting agent through the Ca/Mg ratio and secondly, as a neutralizing agent of organic acids in the plant. The element calcium is one of the components of the middle lamella of the cell wall. It is thought that calcium may enter into the composition of the protoplasm and certain types of protein in the cell. As to the effects of calcium deficiency in plants, the following are observed symptoms:

(a) Calcium deficiency causes lower leaves to roll in at the margins and to become chlorotic.

(b) Lack of calcium causes translocation of carbohydrates.

(c) Lack of calcium is responsible for a low rate of absorption and accumulation of nitrates by the plant.

(d) Lack of calcium definitely reduces the size of the roots and absence of it may cause them to die.

It is obvious that magnesium performs many important functions in plant growth and development (14).

(a) Magnesium composes 2.7% of the chlorophyll molecule.

(b) Magnesium deficiency adversely affects chlorophyll formation.

(c) Magnesium is a phosphate carrier and will assist the plant in absorbing this element.

(d) Magnesium usually is found in high concentration in the seed and fruit of the plant.

(e) Low carbohydrate content of plants is associated with low magnesium content.

(f) Magnesium is important in nitrogen fixation activities of soybeans.

(g) Magnesium stimulates reduction processes in plants.

Hinkle and Eisenmenger (7) made a study to determine the effect of magnesium deficiency on the production of chloroplast pigments in the plant. They found that in the case of severe magnesium deficiency the plants lost chlorophyll, xanthophyll, and carotene in the ratio of 20-2-1 respectively. The addition of calcium did not seem to increase or decrease the losses due to magnesium deficiency.

Hunter (8) made a study of Ca/Mg ratio in alfalfa using Hardin loam soil. He used Ca/Mg ratios varying from 1/4 to 32/1. He concluded from the results of his experiments that the weight of the alfalfa produced was not affected by varying Ca/Mg ratios. He also observed that the percent of phosphorus in the plant increased with a reduced Ca/Mg ratio. The percentage of lignin was unaffected by any treatment.

The New Jersey Agricultural Experiment Station (5) reports that heavy applications of potassium to certain New Jersey soils caused an increase in magnesium deficiency. Also all applications of magnesium increased yields. Furthermore, it was observed that soluble sulfate and oxide forms were more effective than dolomitic limestone in overcoming the deficiency. Less than 20% of the soils tested had optimum amounts of magnesium.

In working on the problem of the influence of calcium on the availability of other soil cations, Bear and Toth (6) arrived at these conclusions, "Conditions approach the optimum for the cation nutrition of alfalfa when 65% of the exchange complex of the soil is occupied by calcium; 10% by magnesium; 5% by potassium and 20% by hydrogen." In further work on the related topic, Bear and Prince (4) made the following observations:

(a) High yield of alfalfa was associated with high available calcium in the soil at the start of the test.

(b) When all fertilizer elements were applied before seeding, the uptake of potassium was too great at first, leaving a deficiency later on.

(c) They concluded that potassium should be applied annually at a rate to keep the plant content at a minimum of one percent but not at a rate so large as to bring about a substitution of potassium for calcium and magnesium in the functions that are common to all three cations in the soil.

Albrecht and Horner (2), in a study of nitrogen fixation by soybeans, found that the variation of the efficiency of the plant in nitrogen fixation is more closely coordinated with the supply of calcium than with differences in soil pH. In further study with over four hundred Missouri soils, Albrecht (1) found that a close relationship existed between decreasing supply of calcium and decreasing productivity of the soil. Other observations include:

(a) Increased calcium utilization in legumes increased the amount of protein harvested, according to Albrecht and Smith (3).

(b) Soil liming is primarily a means of feeding calcium to the crop and making P available rather than modifying soil pH.

Troug (12) observed that occasionally the application of lime to sandy soils has reduced crop yields. The reason for this apparently lies in reduced availability of boron and manganese. Troug concluded that excess lime in sandy soil, which is low in organic matter, makes boron and manganese less available.

EXPERIMENTAL METHODS

Materials and Methods

Three typical Kansas soils were included in this investigation. These soils included Albion loam from the Kingman Experiment Field, Parsons silt loam from the Thayer Experiment Field and Cherokee silt loam from the Columbus Experiment Field.

In each case the soil was obtained from the plow layer. The soil material was crushed, mixed thoroughly and 200 gm aliquots were placed in glazed earthware pots.

The experiment incorporated the following principal features:

(1) A uniform application of nitrogen and phosphorus was made to each pot so as to eliminate possible deficiencies of these elements. This application amounted to 0.4 gm NH_4NO_3 and 1.0 gm $Ca(H_2PO_4)_2$.

(2) Eight soil treatments were employed in duplicate. These treatments included applications of Ca, K and Mg alone and in all possible combinations. Duplicate cultures

of each soil to which none of these elements had been added served as controls.

(3) Plants utilized included ladino clover, soybeans and spring wheat.

An outline of the treatments is provided below.

TREATMENT	CHEMICALS USED	AMOUNT (GM 1 POT)
1. No treatment	--	--
2. Ca	$CaCl_2 \cdot 2H_2O$	4
3. K	KCl	2
4. CaK	$CaCl_2 \cdot 2H_2O + KCl$	4 + 2
5. Mg	$MgCl_2 \cdot 6H_2O$	2
6. CaMg	$CaCl_2 \cdot 2H_2O + MgCl_2 \cdot 6H_2O$	4 + 2
7. KMg	$KCl + MgCl_2 \cdot 6H_2O$	2 + 2
8. CaKMg	$CaCl_2 \cdot 2H_2O + KCl + MgCl_2 \cdot 6H_2O$	4 + 2 + 2

Cultural Techniques

After soil preparation, soybeans were planted in one series of pots and ladino clover in the other series of pots for each soil material. After satisfactory stands of each crop were obtained, the soybeans were thinned to two plants per pot and the ladino clover was thinned to sixteen plants per pot. After this, regular watering was the only care given to each of the crops until harvest.

The soybeans were planted October 24, 1951 and harvested January 1, 1952. The ladino clover was planted November 12, 1951 and the first cutting harvested January 29, 1952. The second cutting was harvested March 5, 1952. The third cutting on Cherokee silt loam and Parsons silt loam soils was taken April 3, 1952. The third cutting from Albion loam soil was delayed until April 18 because of insufficient growth. A fourth cutting was taken from the Cherokee silt loam soil on May 5, 1952. The soybean plants were clipped at ground level and allowed to dry four days at a temperature of about 75 degrees. The ladino clover was clipped about one inch above the ground and was dried in a similiar manner.

After removal of the soybean crop, wheat was planted in these same cultures on January 10, 1952. The wheat was harvested May 12, 1952, and dried in the same manner as the clover and soybeans. However, the wheat straw and heads were harvested separately. After preliminary drying each sample of plant material was ground and placed in previously labeled glass or metal containers. The samples were then oven dried at a temperature of 105 degrees Centigrade for a twelve hour period.

Laboratory Preparation

After the ground plant material was oven dried it was removed and allowed to cool in large dessicators. One gram samples of plant material were placed in 250 ml beakers. To each of these samples 2 ml of sulfuric, 15 ml of nitric, and 4 ml of perchloric acid were added. Each beaker was then covered with a watch glass and placed on a hot plate. After approximately two hours of digestion the clear digest was removed and allowed to cool. The digest was then transferred to 100 ml volumetric flasks and diluted to the mark. These preparations were used for chemical analyses.

Analytical Techniques

Phosphorus. After the plant material had been digested and the clear residue diluted to 100 ml, the phosphorus content was determined. This determination was made by use of the Coleman Jr. spectrophotometer. The procedure in this determination was as follows.

A 1 ml aliquot of the above solution was made to 10 ml volume with distilled water. One-half ml each of ammonium molybdate solution and reducing reagent were added. Each tube was allowed to stand fifteen minutes after the addition of the reducing reagent. Spectrophotometer readings were made then. These readings were translated into ppm P by means of a previously prepared standard curve.

Calcium. Calcium content of the plant digest was obtained by use of the Perkin-Elmer flame photometer. No dilution of the plant digest was made.

An internal standard solution containing 1000 ppm calcium and 100 ppm lithium was used in calibrating the instrument. Dial readings were converted to ppm by use of a standard curve prepared previously by the use of standard solutions.

Magnesium. Magnesium content of the plant material was determined by the method of the U. S. Regional Salinity Laboratory (10). The essential features of this procedure were as follows.

A sample of the plant digest containing .005 to .08 me of calcium was transferred by pipette to a centrifuge tube. Oxalic acid (0.2N) was used to precipitate the calcium. After heating in a steam bath and making the solution slightly alkaline with ammonium hydroxide, the tubes were centrifuged. The supernatant liquid was decanted for magnesium determination.

The magnesium was then precipitated with 3 percent ammonium chloride solution and 5 percent ammonium dihydrogen phosphate solution. The precipitate was dissolved in approximately 5 N sulfuric acid. Equal amounts of 5 percent ammonium molybdate and 0.25 percent ammonium vanadate solutions were added to the dissolved precipitate. A colored solution containing the magnesium complex was formed.

Readings of light transmission for these colored solutions were obtained by use of the Evelyn photoelectric colorimeter. Comparisons were made with a curve prepared previously by use of standard magnesium solutions.

Potassium. The potassium content of the plant digest was determined by the use of the Perkin-Elmer flame photometer. The plant digest was diluted 1 to 10 with water for all samples produced on soil to which potassium had been added at the beginning of the experiment. All plant digest samples from soil which had received no initial potassium application were diluted 1 to 5 with water.

An internal standard solution containing 40 ppm potassium and 100 ppm lithium was used to calibrate the instrument. Dial readings were then converted to ppm K with the use of a curve previously prepared by obtaining readings from standard solutions containing known amounts of potassium.

EXPERIMENTAL RESULTS

Yield Data

Yield data for the entire experiment are summarized in Tables 1 to 5 inclusive. In the case of ladino clover, the yields are summarized by cuttings for each of the three soils used in this experiment.

Statistical analyses of all data were performed to evaluate the significance of all results obtained. The major portion of this discussion of experimental results will deal only with that portion of the data having statistical significance.

Table 1 contains a summary of wheat yields on all soils for all treatments. The Albion loam soil produced a highly significant difference in both grains and straw yields as a result of soil treatments. All treatments showed significantly greater yields than did cultures receiving no treatment. In the case of both grain and straw the largest yield occurred as a result of the combination of Ca, K and Mg. The largest yield increase obtained by the application of a single element was brought about by the application of Ca. Mg applied alone gave the smallest yield increase. However, the effect of Ca applied alone was not significantly greater than that of Mg alone. The combination of applied Ca and K produced the second largest yield of both wheat grain and straw.

The wheat yield on Parsons silt loam soil showed no significant increase or decrease due to soil treatment.

Table 1. Effect of Chemical Soil Treatment on Mean[1] Yield of Wheat Grain and Straw on Several Kansas Soils.

SOIL TREATMENT	YIELD (Gm/Pot)					
	Albion Loam		Parsons Silt Loam		Cherokee Silt Loam	
	Grain	Straw	Grain	Straw	Grain	Straw
No Treatment	0.60	0.88	4.46	3.68	5.56	5.12
K	2.22	2.48	5.56	5.50	4.90	5.06
Mg	1.87	2.23	4.89	4.20	5.84	5.32
KMg	2.91	3.20	4.41	4.11	5.88	6.84
Ca	2.46	2.51	3.48	3.44	6.65	6.19
CaK	3.36	3.67	3.70	3.54	5.54	6.18
CaMg	2.46	2.92	4.75	4.10	4.18	4.14
CaKMg	4.54	3.90	2.83	3.20	3.88	4.14
Least Significant (.05)	.87	.46	N.S.	N.S.	1.17	1.29
Difference (.01)	1.28	.68	N.S.	N.S.	1.73	N.S.

[1] Mean of duplicate cultures

Cherokee silt loam soil produced significant differences in yields due to treatment effects. However, treatments which produced significant differences tended to reduce grain yields. The greatest reduction of yield was brought about by the combination of Ca, K and Mg. The combination of Ca and Mg also reduced yields of grain significantly. No significant reduction of straw yields occurred as a result of treatments. Increased straw yields were obtained where Mg was used alone and also where Mg was applied in combination with K. Other treatments responsible for increased straw yields were Ca alone and the combination of Ca and K.

In summarizing the effect of soil treatments on yield of wheat grain and straw, a few definite conclusions may be made. In the first place, Albion loam soil gave a definite response to each soil treatment. The combination of Ca, K and Mg gave the greatest yield response. Since all cultures received uniform applications of nitrogen and phosphorous, it would appear that restricted plant growth was due to a lack of exchangeable cations in the original soil. In the second place, Parsons silt loam soil did not respond significantly to any of the treatments. Since no significant yield differences were obtained from ladino clover grown on this soil, it would appear that Thayer soil contains adequate amounts of each Ca, K and Mg in the exchangeable form to support normal plant growth. Finally, the negative response of Cherokee silt loam soil to the combination of Ca and Mg or to the three cations combined (Ca, K and Mg) is difficult to explain. One might speculate on the possibility that this addition of chemicals had a tendency to upset the nutrient element balance in the soil. However, since three of the treatments actually increased the yield of straw, the above speculation seems somewhat unwarranted. The negative effect was observed only for grain yields.

As previously explained, no significant treatment effects on yields were observed on any of the ladino clover cuttings taken from Parsons silt loam soil. The same condition prevailed with respect to Albion loam soil. However, significant yield differences occurred between treatments on Cherokee silt loam soil except for the first cutting. Applied K produced a significant increase in second cutting clover yield. The third and fourth cutting yields followed the same pattern but the increases were not significant. The combination of Ca, K and Mg also produced an increase in yield of second cutting ladino clover. No other significant increases in yield were observed.

Significant decreases in yield were observed for treatments of Mg alone, for the combination of K and Mg, and also for the combination of Ca and Mg. These decreases were observed for second, third and fourth cuttings. This indicates an undesirable effect of Mg on nutrient uptake by the plant. Ca alone caused a reduction in yield for both second and third cuttings of ladino clover. Here again it is difficult to point out why ladino clover yields were reduced by the application of Ca. Data for ladino clover yields are summarized in Tables 2, 3 and 4.

Table 2. Effect of Chemical Soil Treatment on Mean[1] Yield of Ladino Clover, Albion Loam Soil.

SOIL TREATMENT	YIELD (Gm/Pot) by Cutting			
	First	Second	Third	Total
No Treatment	2.85	1.43	1.70	5.97
K	2.76	1.21	1.49	5.46
Mg	1.90	1.25	1.48	4.63
KMg	1.60	1.16	1.60	4.36
Ca	1.57	0.69	1.50	3.76
CaK	1.48	1.12	1.31	3.91
CaMg	1.30	1.02	1.27	3.60
CaKMg	0.66	0.57	1.56	2.79
Least Significant (.05)	N.S.	N.S.	N.S.	
Difference (.01)	N.S.	N.S.	N.S.	

[1] Mean of duplicate samples

Table 3. Effect of Chemical Soil Treatment on Mean[1] Yield of Ladino Clover, Parsons Silt Loam Soil.

SOIL TREATMENT	YIELD (Gm/Pot) by Cutting			
	First	Second	Third	Total
No Treatment	2.14	2.96	2.57	7.67
K	1.86	3.05	2.74	7.66
Mg	1.28	2.09	3.39	6.76
KMg	0.87	1.76	3.06	5.70
Ca	0.76	2.08	2.38	5.22
CaK	1.46	2.18	3.80	7.44
CaMg	0.46	1.85	1.73	4.04
CaKMg	0.34	0.89	1.78	3.00
Least Significant (.05)	N.S.	N.S.	N.S.	
Difference (.01)	N.S.	N.S.	N.S.	

[1] Mean of duplicate samples

Table 4. Effect of Chemical Soil Treatment on Mean[1] Yield of Ladino Clover, Cherokee Silt Loam Soil.

SOIL TREATMENT	YIELD (Gm/Pot) by Cutting				
	First	Second	Third	Fourth	Total
No Treatment	3.24	3.94	5.31	4.48	16.96
K	2.86	4.39	5.88	5.18	18.31
Mg	2.35	3.43	4.22	3.52	13.52
KMg	1.93	3.21	4.28	3.43	12.84
Ca	2.16	3.39	3.91	4.12	13.57
CaK	2.35	3.69	4.65	4.12	14.80
CaMg	2.24	3.15	4.13	3.52	13.04
CaKMg	2.83	4.44	5.38	3.68	16.33
Least Significant (.05)	N.S.	.25	1.14	.89	
Difference (.01)	N.S.	.37	1.70	1.32	

[1] Mean of duplicate samples

Soybean yield data are summarized in Table 5. It can be observed readily that all treatments caused a reduction in yield on all soils. It appears that the high concentration of chemicals was toxic to the soybean plant. All the plants except those on no treatment pots tended to wither prematurely.

Chemical Composition of Plant Material

Soybeans. Data relative to the chemical composition of the soybeans are contained in Tables 6, 7 and 8.

No significant differences were observed in plant content of phosphorous. A significant increase in potassium content was observed for all treatments where this element was applied. The above statements held true for all three soils used in the experiment.

The uptake of calcium by the soybean plant varied considerably according to the soil upon which this crop was grown. Significant increases in calcium percentage composition was indicated for the Parsons silt loam soil where this element was applied to the soil at the beginning of the experiment. However, Cherokee silt loam soil produced a significant increase in plant calcium content only where Ca, K and Mg were applied in combination. Also, a decrease in calcium content was observed where K was applied alone and in combination with Ca. Soybeans grown on Albion loam soil showed significant increases in calcium uptake on treatments where Ca was applied in combination with the other applied elements. However, no significant increase in calcium uptake by the plant was observed where Ca was the only element applied.

Table 5. Effect of Chemical Soil Treatment on Mean[1] Yield of Soybeans on Several Kansas Soils.

SOIL TREATMENT	YIELD (Gm/Pot)		
	Albion Loam Soil	Parsons Silt Loam Soil	Cherokee Silt Loam Soil
No Treatment	4.40	4.10	4.70
K	3.55	2.55	3.80
Mg	4.10	2.20	4.15
KMg	2.65	1.40	3.35
Ca	3.10	1.45	1.45
CaK	0.45	1.35	2.60
CaMg	1.95	0.95	3.40
CaKMg	0.55	0.15	1.85

[1] Mean of duplicate samples

Table 6. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Soybeans, Parsons Silt Loam Soil.

SOIL TREATMENT	Mean Chemical Composition (%)		
	P	K	Ca
No Treatment	.422	1.75	1.78
K	.406	2.71	1.52
Mg	.357	1.55	1.55
KMg	.319	2.42	1.95
Ca	.360	1.80	2.11
CaK	.412	3.05	2.87
CaMg	.375	1.78	2.39
CaKMg	.428	3.30	2.35
Least Significant (.05)	N.S.	.66	.32
Difference (.01)	N.S.	.98	.47

[1] Mean of duplicate samples

Table 7. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Soybeans, Cherokee Silt Loam Soil.

SOIL TREATMENT	Mean Chemical Composition (%)		
	P	K	Ca
No Treatment	.478	1.33	2.44
K	.429	1.89	2.07
Mg	.332	1.16	2.28
KMg	.404	2.07	2.51
Ca	.530	1.55	2.65
CaK	.428	1.98	2.16
CaMg	.332	1.25	2.20
CaKMg	.439	2.13	3.44
Least Significant (.05)	N.S.	.24	.27
Difference (.01)	N.S.	.35	.39

[1] Mean of duplicate samples

Table 8. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Soybeans, Albion Loam Soil.

SOIL TREATMENT	Mean Chemical Composition (%)		
	P	K	Ca
No Treatment	.956	1.77	2.16
K	.689	2.67	2.30
Mg	.489	1.53	1.94
KMg	.500	2.56	2.45
Ca	.464	1.63	2.27
CaK	.456	3.22	3.06
CaMg	.637	1.83	2.84
CaKMg	.583	3.05	2.82
Least Significant (.05)	N.S.	.39	.47
Difference (.01)	N.S.	.58	.70

[1] Mean of duplicate samples

It must be noted that the soybean crop did not develop normally on any of the cultures where chemical treatment was applied. During the growing period of the soybean plant it appeared that something in the soil solution was toxic to the plant. Since all treatments had some tendency to reduce soybean yields, no individual element can be charged with this effect.

Ladino Clover. Ladino clover was grown on each of the three soils used in the experiment. Three cuttings each were taken from the Albion loam soil and from the Parsons silt loam soil, and four cuttings from the Cherokee silt loam soil. The composition of plants with respect to phosphorus, potassium, calcium and magnesium is summarized in Tables 9, 10 and 11.

On the Parsons silt loam soil, no significant influences from chemical soil treatment were noted with respect to content of phosphorus of the first cutting of plant material. However, for the second cutting several differences were observed. Combinations of Ca and K and Ca, K and Mg resulted in a slight decrease in the content of phosphorus in the plants. All other applications of those elements resulted in an increased content of phosphorus in the plant material. Mg alone and the combination of Ca and Mg were the treatments responsible for the greatest increase in content of phosphorus. A high content of phosphorus in the plant material from cultures of the third cutting changed the pattern of results observed in the second cutting, however. There was little evidence that applications of Mg resulted in a greater content of phosphorus in the plant material.

Table 9. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Ladino Clover, Parsons Silt Loam Soil.

SOIL	Mean Chemical Composition (%)											
	P			K			Ca			Mg		
TREATMENT	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
No Treatment	.403	.374	.598	1.79	0.96	0.98	1.37	1.16	1.66	.417	.486	.551
K	.423	.388	.374	3.81	3.77	3.06	1.57	0.90	1.31	.411	.432	.434
Mg	.430	.407	.369	1.76	1.32	1.15	1.53	1.08	1.66	.526	.548	.741
KMg	.418	.393	.330	2.91	3.93	3.98	2.22	0.98	1.28	.520	.556	.546
Ca	.423	.385	.382	3.00	1.66	1.44	1.89	1.81	2.61	.484	.514	.593
CaK	.425	.333	.318	5.30	3.49	3.60	1.67	1.48	1.88	.357	.440	.421
CaMg	.439	.385	.391	2.60	1.91	1.87	1.97	1.66	2.33	.643	.544	.676
CaKMg	.459	.339	.461	3.35	4.07	4.06	1.66	1.33	2.44	.448	.464	.609
Least Significant (.05)	N.S.	.014	.045	.26	.40	.44	.35	.14	.33	.052	N.S.	.066
Difference (.01)	N.S.	.022	.067	.38	.59	.65	N.S.	.21	.49	.073	N.S.	.098

[1] Mean of duplicate samples

Table 10. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Ladino Clover, Cherokee Silt Loam Soil.

SOIL TREAT- MENT	Mean Chemical Composition (%)															
	P				K				Ca				Mg			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
No Treatment	.442	.429	.389	.355	2.80	1.28	1.00	0.68	2.03	1.49	1.93	2.20	.410	.473	.531	.471
K	.429	.338	.345	.283	4.85	3.98	3.98	2.47	1.87	1.28	1.62	1.48	.308	.352	.306	.462
Mg	.444	.396	.360	.318	2.85	1.54	1.17	0.78	1.83	1.48	2.03	2.11	.482	.504	.575	.634
KMg	.495	.453	.330	.397	4.85	4.04	3.56	2.47	1.94	1.49	2.65	1.86	.446	.446	.407	.589
Ca	.451	.418	.413	.387	2.90	1.61	1.19	0.91	2.22	1.96	2.82	2.52	.382	.290	.416	.509
CaK	.406	.403	.391	.285	4.61	3.98	3.66	2.07	2.17	1.48	2.11	2.46	.314	.473	.291	.444
CaMg	.402	.423	.401	.401	2.75	1.45	1.28	0.93	2.15	1.57	2.61	3.12	.453	.447	.430	.653
CaKMg	.385	.339	.319	.225	4.10	3.62	3.45	2.16	1.89	1.14	1.82	2.51	.432	.434	.362	.571
Least Significant (.05)	.026	.047	.029	.021	.45	.53	.22	.12	N.S.	.26	.27	.28	.048	N.S.	.095	.052
Difference (.01)	.038	.070	.043	.030	.66	.79	.33	.19	N.S.	.38	.41	.42	.071	N.S.	.140	.076

[1] Mean of duplicate samples

Table 11. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Ladino Clover, Albion Loam Soil.

SOIL TREATMENT	Mean Chemical Composition (%)											
	P			K			Ca			Mg		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
No Treatment	.457	.737	.887	1.78	2.34	2.02	1.17	1.20	1.62	.327	.363	.423
K	.374	.392	.534	2.86	2.79	2.75	1.13	1.23	2.26	.405	.320	.386
Mg	.385	.481	.541	1.61	2.66	2.26	1.37	1.28	1.66	.511	.532	.513
KMg	.424	.418	.382	2.75	2.86	2.94	1.16	1.24	1.83	.478	.474	.598
Ca	.394	.454	.444	1.70	1.74	2.04	2.17	1.63	2.37	.390	.416	.444
CaK	.435	.398	.329	3.42	2.32	2.75	1.96	2.04	2.36	.421	.452	.530
CaMg	.420	.438	.337	2.44	2.48	1.69	2.28	1.51	2.18	.556	.490	.617
CaKMg	.437	.382	.223	2.88	2.74	2.73	2.62	2.08	2.51	.517	.497	.608
Least Significant (.05)	.030	.062	.040	.33	.39	.16	.20	.26	.06	.094	.067	.054
Difference (.01)	.044	.092	.058	.49	.57	.23	.29	.39	.09	.139	.100	.080

[1] Mean of duplicate samples

Applied K resulted in a considerable increase in content of potassium in the plant. The combination of applied Ca and K was responsible for the highest content of potassium at the first cutting. However, second and third cutting analyses revealed that the highest content of potassium resulted from the Ca, K and Mg combination.

First cutting plant material reflected no specific pattern with respect to calcium uptake. Data for the second and third cuttings clearly reflected an increase in the uptake of this element as a result of Ca applications to the soil. Apparently some repression of calcium accumulation resulted from the applications of K. Repressive effects of Mg applications on the accumulation of calcium were not noted.

Content of magnesium of the plant material was greatest for each of the three cuttings when this element was applied to the soil alone or in combination with calcium. Applications of K to the soil were generally reflected in a lower content of magnesium in the plant material.

A review of the chemical composition data for ladino clover grown on Cherokee silt loam soil revealed certain relationships.

Content of phosphorus was generally lowest in those plants produced on cultures which included the combination of Ca, K and Mg as a treatment. The greatest content of phosphorus in plant material for the first and second cuttings was produced by cultures which received the combination of K and Mg as a treatment. This treatment apparently failed to affect significantly the content of phosphorus in the third cutting of plant material but it did produce an increased content of phosphorus in the fourth cutting. The Ca treatment also was responsible for a sizeable increase in content of phosphorus in ladino clover in all except the second cutting of plant material.

The Cherokee silt loam soil responded markedly to treatments involving applied K. The content of potassium of the plant material produced where K was applied alone and in combination with Mg was two to four times as great as that observed where none was applied. Applications of cations other than K had little effect upon the content of potassium in ladino clover produced in cultures of Cherokee silt loam soil.

Applications of Ca, alone or in combination with other cations, had a distinct tendency to increase the calcium content of the ladino clover plants. This was not accompanied by yield increases, however. Potassium when applied alone or in combination with Ca and Mg tended to repress the calcium content of the ladino plants.

The application of Mg alone to the Cherokee silt loam was the only treatment resulting in a consistent increase in the magnesium content of the plant. The fourth cutting of plant material was the only one in which all soil treatments that included Mg reflected an increased content of this element in the plants. A steady increase in the plant content of magnesium from the first through the fourth cutting was observed where Mg was applied alone to the soil. When applied alone, K tended to repress the magnesium content of the plant material. This relationship was true for each cutting.

Chemical soil treatments exhibited a tendency to cause a restricted uptake of phosphorus by the ladino clover plants produced on the Albion loam soil. This situation was especially noticeable with both the second and third cuttings of plant material. Also, data from the above cuttings revealed that phosphorus uptake by the plant was least restricted where Mg alone was applied to the soil. These data also tend to indicate that greatest restriction of phosphorus uptake was brought about when the combination of Ca, K and Mg was applied to the soil.

Applied K was responsible for a substantial increase in potassium content of the ladino clover plant as shown by the data of Table 11 for the first cutting. These same comparisons for the second cutting of plant material indicated that treatments which included K had much less effect on potassium uptake by the plant than was observed with first cutting. Actually, no increase in potassium content of plant material occurred at the second cutting as a result of the application of the combination of Ca and K.

Data for the third cutting somewhat corresponded with those of the first cutting except that relative increases in potassium content were somewhat lower.

All treatments involving the application of Ca to the soil resulted in an increased calcium content of the plant material. The application of Ca alone had a tendency to lower the potassium content of the ladino clover plants.

The application of Mg alone produced the greatest increase in magnesium content of the plant only at the time of the second cutting. First and third cutting data suggest that the greatest magnesium content of the plant material occurred as a result of the combination of Ca and Mg and the combination of Ca, K and Mg. These relationships suggest that both calcium and potassium exerted a favorable influence with respect to the accumulation of magnesium by ladino clover plants grown on the Albion loam soil. A more complete study of the data suggested that Ca was more beneficial than was potassium toward facilitating the accumulation of magnesium by the plants.

In comparing the relative responses of the three soils to applied cations some parallel patterns in uptake of the cations by the ladino clover plant were noted. Ca, when applied alone, exerted a favorable influence toward the accumulation of potassium. Magnesium, when applied alone, did not result in increased potassium content of ladino clover plants. Magnesium and phosphorus contents of the plant material did not follow clearly defined parallel patterns. However, the greatest phosphorus content of plant material was found among cultures grown on soil which included the element Mg as part of the treatment. Applied Mg did not increase calcium uptake. Applied Ca did, however, tend to increase magnesium uptake on Albion loam soil and Parsons silt loam soil.

Wheat Grain. Table 12 contains a summary of the chemical composition of wheat grain produced on various cultures of each of the three soils used in the experiment. No determination of calcium content was included because the concentration of this element in the grain was too low to permit accurate measurement

Table 12. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Wheat Grain on Several Kansas Soils.

SOIL	Mean Chemical Composition (%)								
	Parsons Silt Loam			Cherokee Silt Loam			Albion Loam		
TREATMENT	P	K	Mg	P	K	Mg	P	K	Mg
No Treatment	.391	.450	.194	.429	.476	.176	.149	.284	.117
K	.405	.452	.165	.396	.457	.157	.405	.518	.149
Mg	.279	.420	.185	.448	.494	.183	.422	.469	.191
KMg	.379	.452	.173	.428	.457	.166	.386	.476	.173
Ca	.353	.462	.151	.432	.458	.196	.446	.494	.172
CaK	.513	.512	.172	.432	.476	.173	.476	.483	.153
CaMg	.385	.469	.172	.472	.452	.179	.456	.512	.189
CaKMg	.512	.519	.209	.489	.469	.177	.466	.543	.183
Least Significant (.05)	.044	N.S.	.018	.041	N.S.	N.S.	.046	.040	N.S.
Difference (.01)	.065	N.S.	.026	N.S.	N.S.	N.S.	.068	.059	N.S.

[1] Mean of duplicate samples

with the flame photometer.

Wheat grain produced on the Cherokee silt loam soil reflected no significant variations in uptake of elements as a result of chemical soil treatment.

Uptake of cations on the Parsons silt loam soil was influenced by treatments. Applications of Mg alone tended to reduce phosphorus content. No significant differences in potassium content were observed. Slight but nevertheless significant differences in magnesium content of grain were observed. The lowest magnesium content was found in the grain produced on soil receiving an application of Ca alone. The treatment combination of Mg, K and Ca resulted in the greatest magnesium content of the grain. Wheat grain produced on the Albion loam soil showed a considerable increase in phosphorus uptake due to applications of the various cations, alone or in any combination. The Ca-K soil treatment resulted in a three fold increase in phosphorus content of the grain. Nearly as great an increase was observed for each of the other treatments. Potassium uptake also was increased by each soil treatment. The above element was found in greatest concentration in plant material produced on soil receiving the combination of Ca, K and Mg. No significant increase in magnesium content of the grain was observed as a result of soil treatment on content of the grain was observed as a result of soil treatment on the Albion loam.

Wheat Straw. All data with respect to chemical composition of the wheat straw for each of the soils are summarized in Table 13. Phosphorus content of the straw was so low that

Table 13. Effect of Chemical Soil Treatment on Mean[1] Chemical Composition of Wheat Straw on Several Kansas Soils.

SOIL TREATMENT	Mean Chemical Composition (%)									
	Parsons Silt Loam			Cherokee Silt Loam			Albion Loam			
	Ca	K	Mg	Ca	K	Mg	Ca	K	Mg	P
No Treatment	.33	.27	.398	.36	.45	.259	.23	.57	.152	.171
K	.55	1.26	.257	.44	1.25	.172	.43	1.14	.204	.129
Mg	.64	.46	.502	.44	.50	.264	.50	.70	.257	.111
KMg	.48	1.30	.320	.42	1.24	.189	.42	1.26	.261	.119
Ca	.86	.44	.296	.60	.54	.264	.68	1.21	.248	.184
CaK	.86	1.45	.243	.80	1.15	.213	.82	1.38	.256	.201
CaMg	1.10	.59	.490	.88	.62	.328	.80	1.22	.312	.239
CaKMg	.96	1.36	.401	1.04	1.20	.325	.78	1.43	.321	.196
Least Significant (.05)	.146	.111	.110	.113	.025	N.S.	.063	.096	.043	.039
Difference (.01)	.216	.165	.163	.168	.037	N.S.	.093	.142	.063	.057

[1] Mean of duplicate samples

satisfactory analyses could not be obtained for the material produced by the Parsons silt loam and Cherokee silt loam soils.

For the Parsons silt loam soil, all applications of Ca resulted in an increased content of this element in the straw. The combination of Ca and Mg was responsible for the greatest uptake of calcium.

Applied K tended to increase the content of this element in the straw. With respect to potassium content, it was observed that a greater content of this element occurred when K was applied in combination with Ca than when applied in combination with Mg.

The most outstanding aspect of magnesium content of the straw was the repressing effect observed for K applications. Applications of Mg resulted in an appreciable increase in magnesium content of the straw.

A study of the composition of the straw produced on cultures of Cherokee silt loam soil revealed no significant differences with respect to content of magnesium. However, applied Ca brought about a sizeable increase in the content of this element in the straw. The combination of Ca, K and Mg resulted in the largest content of calcium in the wheat straw.

Applied potassium more than doubled the concentration of this element in the straw. Neither calcium nor magnesium, nor the combination of the two, had any appreciable effect on the potassium content of the straw.

The chemical composition of wheat straw from Albion loam soil closely resembled that obtained for straw grown on Parsons silt loam soil. However, the magnesium content of straw from the Albion loam soil was lower than that in the straw produced on the Parsons silt loam soil. Applied Ca facilitated the accumulation of potassium in plants grown on the Albion loam soil. This same treatment was only moderately effective with respect to potassium accumulation in straw produced on the Parsons silt loam soil. Applied K did not exert a repressive effect on magnesium uptake on the Albion loam soil. However, a repressive effect was evident with the straw produced on the Parsons silt loam soil.

INFLUENCE OF SOIL TREATMENT ON CATION UPTAKE OF PLANTS

Ladino Clover

As indicated in Figs. 1, 2 and 3, there was considerable variation in cation accumulation by the ladino clover plants as a result of soil treatment. Also there was some variation between cuttings.

On Parsons silt loam soil, there was a distinct tendency for applications of any of the elements to increase the total accumulation of cations in the plants, except where Mg was applied alone. The effects of K were especially evident for the first two cuttings.

Accumulation of potassium by ladino clover grown on the Parsons silt loam soil which had received no application of K became less pronounced with each cutting. Expressed on the basis of chemical equivalents of cations accumulated, potassium uptake

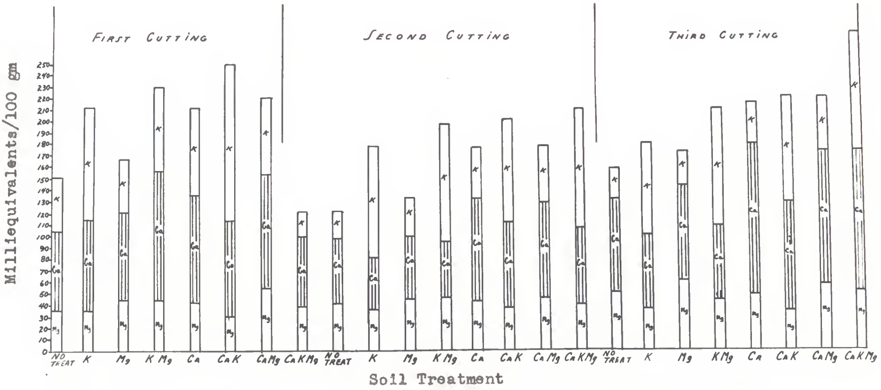

Fig. 1. Effect of soil treatment on cation accumulation by ladino clover, Parsons silt loam soil.

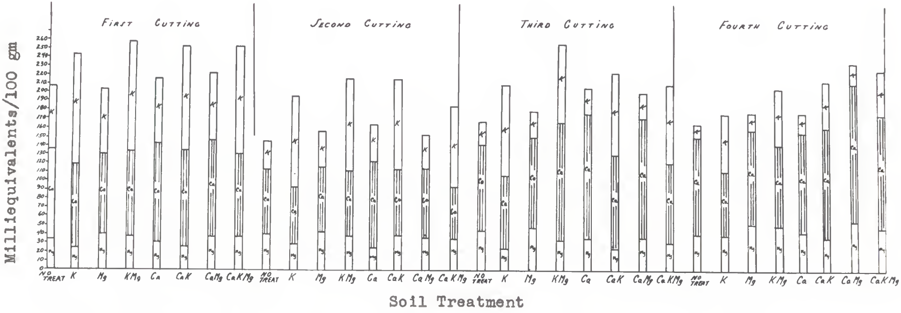

Fig. 2. Effect of soil treatment on cation accumulation by ladino clover, Cherokee silt loam soil.

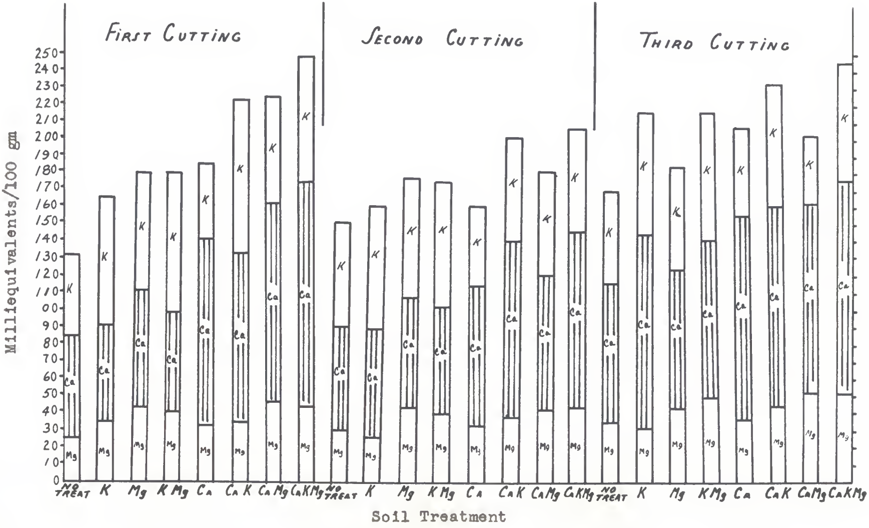

Fig. 3. Effect of soil treatment on cation accumulation by ladino clover, Albion loam soil.

was dominant over magnesium uptake at the first cutting, even where no K had been applied. This tendency was only partially in evidence with the second cutting and at the time of the third cutting, magnesium uptake was dominant over potassium uptake where no K had been applied.

Applications of K generally had the effect of making the uptake of this element completely dominant over both Ca and Mg, even where applications of the other two had been. This might suggest that luxury absorption of potassium occurred on cultures where K was applied.

For Cherokee silt loam soil, there was a greater accumulation of cations in the ladino clover, at the time of the first cutting on the untreated soil than was the case for the Parsons silt loam soil. Apparently there was a sufficiency of each element in the soil. Application of K merely resulted in luxury absorption of this element. Application of either Ca or Mg had little effect.

The accumulation of potassium was markedly less for each of the succeeding cuttings than for the first cutting when the soils which did not receive applications of this element are considered. No doubt such accumulation was insufficient for optimum growth. Some luxury absorption of potassium probably occurred throughout each of the first three cuttings on those cultures where K had been applied. However, this probably was not the case with the fourth cutting.

With respect to dominance of the various elements, it was observed that generally speaking calcium was accumulated in greatest proportions except on the cultures of the second cutting where K had been applied. Accumulation of potassium was dominant over magnesium for the first cutting on cultures which had received no added K. For each of the later cuttings, however, magnesium was accumulated in greater proportions than potassium on such cultures. Accumulation of potassium was always dominant over magnesium where K had been applied to the soil and in some cases it was even dominant over calcium accumulation.

For the Albion loam soil, there was a low total accumulation of cations in the first cutting on the soil which received no treatment. This might suggest that there is some characteristic of low productivity associated with the low cation supplying power of this soil. If any one of the three elements was low in accumulation by the plants, it probably was calcium. Two reasons are cited for this belief. First of all, for cultures not receiving an application of Ca, the accumulation of this element from the Albion loam soil was much less than for either of the other sites. Secondly, there was a marked increase in accumulation of calcium as a result of application to the soil. This relationship was true for each of the cuttings. Thus it would appear that a naturally low level of available calcium must exist in the Albion loam soil. Apparently, however, the supplying power of this soil with respect to both potassium and magnesium is relatively more adequate.

Wheat Straw

Apparently cation accumulation in wheat straw produced on the Parsons silt loam soil was substantially greater than on either of the other soils, as indicated in Fig. 4. There was little or no evidence of lack of accumulation of either calcium or magnesium. Accumulation of potassium by wheat straw on the cultures which did not receive added K was at a relatively low level.

Cation accumulation in the straw produced on the Cherokee silt loam soil was at a low level, especially where K was not applied. Accumulation of calcium was at a rather low level where none of this element was furnished to the soil. Cation accumulation on this soil would seem to present a greater fertility problem than on the Parsons silt loam soil.

Much the same situation prevailed with respect to the Albion silt loam soil as existed for the Cherokee silt loam soil. There was even somewhat lower accumulation of cations on the untreated cultures of this soil than on the untreated cultures of Cherokee silt loam. Low total cation supplying power of this soil apparently was the major factor associated with low wheat yields on this soil. Apparently this power was low for each of the three elements.

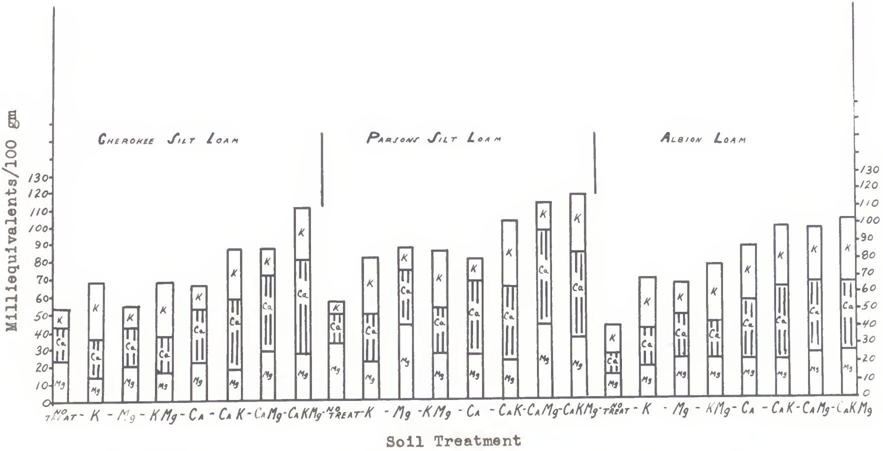

Fig. 4. Effect of soil treatment on cation accumulation by wheat straw.

SUMMARY AND CONCLUSIONS

The soils selected for this experiment were known to be limited in their capacity to produce maximum plant growth. The exact nature of such limitations is not wholly understood. Each of these soils in the field, possessed certain physical properties which are not desirable for maximum crop production. For example, Albion loam soil from Kingman, Kansas, has a low permeability rating. The Cherokee silt loam soil and the Parsons silt loam soil are each characterized by having heavy claypan developments in the B-horizon. The main purpose of this investigation, however, was to determine whether certain chemical aspects of soil fertility might be responsible in part for limitations placed on the productive capacity of the soils under consideration.

Mg, K and Ca were applied to the soil in all possible combinations in an effort to determine whether any of these elements or any combination of these elements would improve soil productivity. Three crops were utilized. These crops were soybeans, ladino clover and wheat.

The over-all yield response due to soil treatments was small. Failure to obtain statistically significant results may have been due in part to rather wide differences in yield obtained from duplicate cultures. In the case of ladino clover, some of this difference might be due to failure to obtain and to keep identical stands. This should not have been a large factor in soybean yield data and should have been only a minor factor with respect to wheat yield data. A definite beneficial response to soil treatment was observed in the case of wheat produced on Albion loam soil. All treatments tended to increase by a substantial amount the yield of both grain and straw. The maximum yield increase in the foregoing case was obtained where a combination of Ca, K and Mg were applied to the soil. No significant response to any of the soil treatments was observed for wheat grown on Thayer soil. Combinations of Ca and Mg and Ca, K and Mg were responsible for wheat yield reductions on the Cherokee silt loam soil. Soil treatments tended to reduce soybean yields on each of the soils. Maximum yield reductions were observed where all three of the elements used in the experiment were applied in combination. This would tend to indicate that the applied salts were in some way harmful to the plant. Observed premature withering of the soybean plants added some weight to this theory.

The ladino clover yield responses to soil treatment were limited in number and small in size. Significant yield differences were not observed on either the Albion loam or Parsons silt loam soils. A positive response to potassium and to the combination of Ca, K and Mg was observed for the second cutting of ladino clover on the Cherokee silt loam soil. A negative yield effect was observed where Mg alone, K and Mg, and Ca, K and Mg were applied to this soil. These data indicate some tendency for Mg to exert a repressive yield effect on ladino clover grown on the Cherokee silt loam soil.

Chemical analyses of plant material were made to determine the effect of soil treatment on chemical composition. In general any element when applied to the soil alone resulted in a higher concentration of this element in the plant. Because of rather wide variations in the pattern of element uptake by soils, few patterns of parallel element uptake or patterns of interactions between the uptake of elements could be established as a result of studying and comparing the data. However, some significant results are as follows:

(1) Applied K tended to repress rather consistently the content of calcium in the plants grown on Parsons silt loam soil and Cherokee silt loam soil.

(2) No parallel pattern in the uptake of magnesium and phosphorus was established. The increased content of phosphorus in successive cuttings of ladino clover plant material produced on the untreated cultures tended to destroy the effectiveness of such comparisons. In many cases, phosphorus uptake was increased by Mg treatments in comparison to treatments receiving no Mg except for the cultures receiving no treatment. Thus no valid parallel pattern was established.

(3) Most of the data seem to substantiate the negative effect of applied K on magnesium uptake. Specifically, this pattern holds true for first, third and fourth cuttings of clover from the Cherokee silt loam soil. It also was observed with first and third cuttings from the Parsons silt loam soil. This negative effect of potassium on magnesium uptake corresponds

with the findings of Tucker (13) who also worked with Cherokee silt loam soil.

Since only greenhouse cultures were used in this investigation it is not possible to make conclusions concerning the field application of these elements. The increased wheat yields on Albion loam soil due to soil treatment suggest a low level of exchangeable cations in the natural soil. Perhaps further study with respect to various ratios of these cations would provide additional information with respect to this soil. Although not significant in all cases, the application of K to Cherokee silt loam soil resulted in increased production of ladino clover. Tucker (13) obtained a highly significant increase in yield of red clover from potassium application to Cherokee sub-soil at the time of the second cutting. From the data on Table 4, it may be observed that K application on Cherokee top soil also gave the largest increase in ladino clover yield at the time of the second cutting. The ladino clover grown on the Cherokee silt loam soil was produced under favorable experimental conditions. An even stand of clover was obtained and maintained throughout the experiment. Significant yield differences were obtained from all cuttings of clover except the first. Duplicate soil cultures varied only slightly in clover yield. Therefore, the repressive effect of applied K on ladino clover yield with respect to Cherokee silt loam soil is rather clearly established by the experimental data. It is hoped that further experimentation will be undertaken with similar soils with respect to both physical and chemical properties.

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EFFECTS OF APPLIED POTASSIUM, MAGNESIUM AND CALCIUM ON THE GROWTH AND CHEMICAL COMPOSITION OF LADINO CLOVER, SOYBEANS AND WHEAT

by

FRANK ELLSWORTH LOWRY

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This investigation was undertaken for two principal reasons. First, an attempt was made to determine whether additions of Ca, K and Mg, alone or in various combinations, stimulated the growth of soybeans, wheat or ladino clover. Secondly, the influence of additions of Ca, K and Mg upon the uptake and accumulation of these elements and phosphorus by the plants mentioned above was investigated.

Three typical Kansas soils were included in this investigation. These soils included Albion loam from the Kingman Experiment Field, Parsons silt loam from the Thayer Experiment Field and Cherokee silt loam from the Columbus Experiment Field.

In each case the soil was obtained from the plow layer. The soil material was crushed, mixed thoroughly and 2000 gm aliquots were placed in glazed earthware pots.

The experiment incorporated the following principal features.

(1) A uniform application of nitrogen and phosphorus was made to each pot so as to eliminate possible deficiencies of these elements.

(2) Eight soil treatments were employed in duplicate. These treatments included applications of Ca, K and Mg alone and in all possible combinations. Duplicate cultures of each soil to which none of these elements have been added served as controls.

(3) Plants utilized included ladino clover, soybeans and spring wheat.

The above crops were planted in soil cultures. Of these soil cultures, all except the controls received chemical applications prior to planting the crops. After emergence, the crops were thinned uniformly. Watering at regular intervals was the only care given to the crops until harvest. Three cuttings of ladino clover were taken from Parsons silt loam and Albion loam soil cultures. Four cuttings of ladino clover were taken from Cherokee silt loam soil cultures. Yield data were obtained from all crops by clipping, oven-drying, and weighing on a torsion balance.

The chemical composition of the plant material with respect to Ca, Mg, K and P was determined.

The effect of soil treatment on soybean yield was of a negative nature. Reduced yield of soybeans due to chemical treatment occurred with all soils. The concentration of chemical salts appeared to be toxic to the plants since premature withering was observed during plant growth.

Ladino clover yield differences due to soil treatment were not significant in the case of plant cultures from Parsons silt loam and Albion loam soil. Soil treatment was responsible for significant yield differences on Cherokee silt loam soil. Applied K resulted in an increase in second cutting yield of ladino clover. Application of K, Ca, and Mg to the soil also increased yields of the above mentioned crop. Combination of Ca and Mg had a tendency to repress ladino clover yields.

Yield data for wheat indicated a great variation in treatment effect between the three soils used in this experiment. On Albion loam soil, highly significant yield increases were observed for all soil treatments. The maximum yield was produced on soil receiving K, Ca, and Mg in combination. In contrast, no significant wheat yield differences were obtained on Parsons silt loam soil. The yield of both wheat grain and straw was significantly increased by an application of Ca to Cherokee silt loam soil. Straw yield on the foregoing soil also was increased significantly by the combination of K and Mg and by the combination of Ca and K. Soil treatments including the combination of Ca and Mg and Ca, Mg, and K resulted in decreased yields of wheat grain and straw.

Chemical analyses of all plant material were performed in order to study the relationship between cation composition of the plant and chemical soil treatment. Chemical composition of the plant with respect to calcium, potassium, magnesium and phosphorus was determined. In general, any element when applied to the soil alone resulted in a higher concentration of this element in the plant. Applied K tended to repress rather consistently the content of calcium in the plants grown on Parsons silt loam soil and Cherokee silt loam soil. Except for Albion loam soil, a negative effect of applied K on magnesium uptake by the ladino clover plant cultures was observed.